Early experience of minimally invasive repair of pectus excavatum in RIPAS Hospital

Chee Fui CHONG [1], Shazana NOR [1], Vinod BHASKARAN [2], Zulaidi ABDUL LATIF [2]
[1] Thoracic Unit, Department of Surgery and [2] Department of Anaesthesiology, Raja Isteri Pengiran Anak Saleha Hospital, Brunei Darussalam

ABSTRACT

Introduction: Pectus excavatum (PE) commonly known as sunken chest or funnel chest, is a congenital deformity of the anterior chest wall and is the commonest of all congenital chest wall abnormalities. It can be associated with physical and psychological morbidity. This study evaluates our unit's experience in performing minimally invasive repair of PE (MIRPE) surgery, also known as "NUSS repair" in teenage patients with PE in RIPAS Hospital. **Materials and Methods:** Retrospective data analysis of the first seven cases of MIRPE performed at RIPAS Hospital since November 2011, when our MIRPE service was first introduced. Patients' demographic and operative records of all the cases were retrieved from the Department of Surgery Operation Note database and medical notes. **Results:** There were five males and one female with a mean age of 17 ± 2.3 years (14.6 – 20.7 years) at the time of repair. The mean Haller index, left ventricular ejection fraction, forced expiratory volume in one second (FEV1) and forced vital capacity (FVC) were 7.0 ± 4.2, 68 ± 6.3%, 3.0 ± 1.3 L/sec and 3.6 ± 1.4 L respectively. Six procedures were performed as a primary procedure and one redo for bar displacement exactly four months after the primary procedure. One patient with the highest Haller index of 15.33 required two bars to correct the defect. The mean duration of procedure was 139.6 ± 57.1 min, with improvement in time in the last two cases down to an average of 86.5 min. Pectus bar used consisted of three Park's pectus bar and three Biomet pectus bar. There was one early post-operative complication (wound haematoma) and one late complication (bar displacement) which occurred in the same patient. There was no mortality. All patients were satisfied with their outcomes. **Conclusion:** Our early experience with MIRPE procedure has been satisfactory and with improvement in learning skills, our time for the procedure has come down to under 1.5 hrs.

Keywords: Pectus Excavatum, NUSS repair, Minimally invasive repair

INTRODUCTION

Pectus excavatum (PE), also commonly referred to as sunken chest or funnel chest, is a congenital deformity of the anterior chest wall, characterised by abnormal growth of several ribs and sternum inwards, producing a concave or caved-in appearance of the anterior chest wall. It is the commonest of all con-

Correspondence author: Chee Fui CHONG
Department of Surgery, RIPAS Hospital,
Bandar Seri Begawan BA1710,
Brunei Darussalam.
Tel: +673-2242424 Ext 280, Fax: +673-2333270
E mail: chong_chee_fui@hotmail.com

genital chest wall abnormalities, comprising of about 90% of cases with an incidence of 1 in 300-400 live births and is four times more common in male infants. A positive family history is found in 43-45% of cases. [1, 2] The aetiology is uncertain but there are many theories and, the most popular is hyperplasia or overgrowth of the chrondral plates of the abnormal ribs resulting in posterior displacement of the sternum. [3] Other theories suggested includes abnormalities of diaphragm, rickets, elevated intrauterine pressure or intrauterine compression as a cause of posterior displacement of the sternum. [3] Although objective evidence supporting these theories are lacking, the current leading theory focuses on a morphological abnormality of the collagen matrix, resulting in softening and bending of the ribs inwards during growth and it's close association with several connective tissue disorders. [4]

Most individuals with PE are asymptomatic or better termed 'subsymptomatic' with symptoms becoming more pronounced when they grew older. [5] Most individuals are thin, tall with a potbelly, have forward-drifted shoulders and show typical suppressed growth compared to their peers. [6] Other symptoms include shortness of breath, reduced exercise tolerance, fatigue, chest pain and tachyarrythmias or palpitation. [5] Studies have consistently reported cardio-respiratory limitation such as lower forced vital capacity with restrictive lung patterns, reduced left ventricular ejection fraction and Cardiac index. [7, 8]

Indications for surgical repair were initially thought mainly to be of cosmetic benefit; but, as evidence of cardio-respiratory deficits are quickly accumulating and with the introduction of the 'NUSS' or minimally invasive repair of PE (MIRPE), surgical repair is now indicated for medical reasons. The Haller index which is a ratio of the transverse length of the whole thoracic cavity to the distance between the back of the sternum and the anterior border of the vertebral body at the deepest part of the PE (Figure 1), has been routinely used to judge the severity of PE and, surgical repair is indicated if the Haller index is more than 3.4. [9] The introduction of NUSS or MIRPE has rapidly revolutionised surgical repair, which has now completely replaced the open surgical Ravitch repair. The former procedure involves the introduction of a pre-bent steel bar across the depressed sternum through two small incisions in the lateral chestwall, which is twisted into position to push the depressed sternum outwards. [10] The bar is usually left for 2-3 years to allow for remodelling of the sternum to occur. Surgical results have been satisfactory with evidence of clinical improvement during growth spurts, cardio-respiratory function and psychosocial improvements. [5, 11]

Our unit first started performing MIRPE procedure on 21st November 2011 with a 2-day workshop on PE and MIRPE. This

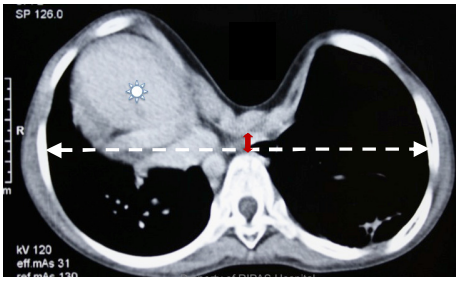


Fig. 1: Haller index is a ratio of the transverse dimension (white broken arrow) to the distance between the posterior of the sternum to the anterior border of the vertebral body (red arrow).

study reports on the unit's early experience with MIRPE since the workshop.

MATERIALS AND METHODS

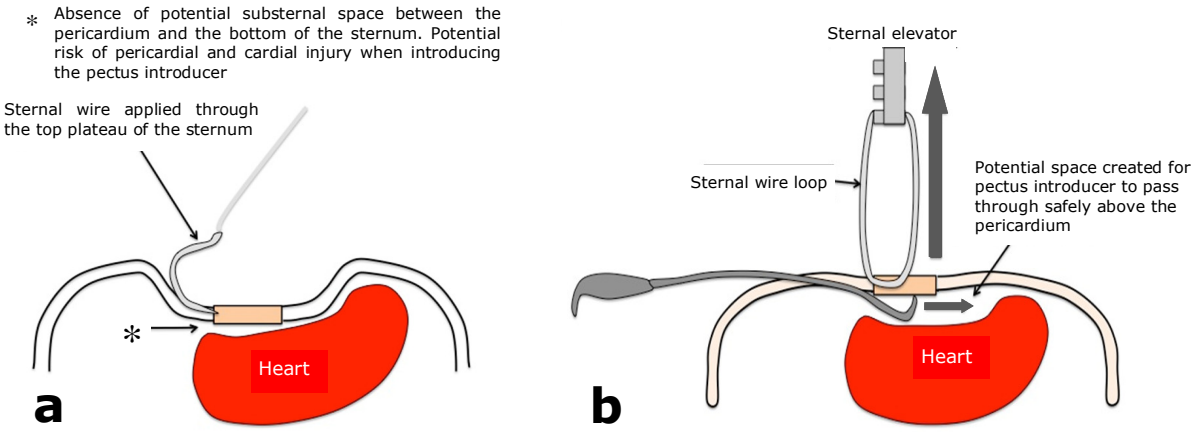
All patients with PE referred to our unit underwent full assessment prior to undergoing MIRPE, which comprised blood investigations, pulmonary function test, electrocardiography, echocardiography, computed tomography (CT) imaging of the thorax and derivation of Haller index. Medical indications for operative repair was a Haller index greater than 3.4 which has been reported to be significantly associated with respiratory and cardiac dysfunction. [9] Indications for operative repair in patients with a Haller index less than 3.4 were based on documented cosmetic-related psychosocial problems. [2]

SURGICAL PROCEDURE: Surgical repair was performed based on Park's modified MIRPE procedure. [12] Patients were prepared and draped in the supine position with both arms extended at the shoulder and flexed at both elbows to 90°, bringing both arms above the head. The shoulders were elevated using a sandbag and the chest exposed completely from the manubrium sterni down to the xiphoid process and both lateral chestwalls and axillae.

The midpoint of the chestwall (sternum) and the lateral exit points in the intercostal spaces at the crest points were first marked (Figure 2). These markings were then transferred to the pectus bar. Pre-bending of the pectus bar was then performed according to the multiple-momentum (MM) based multi-target (MT) Terrain Contour -matching technique such that the pre-bent bar fits snugly into the sternal depression of the PE. [12] If one crest (either the right or left) was higher than the other, then the exit point of the pectus bar at the higher crest is bent shallower than the other end to produce a crest compressive force in order to slightly depressed the higher crest to compensate for the lower crest on the opposite side.

Fig. 2: Marking of deepest part of pectus excavatum, exit crest points on both lateral chestwall, lateral skin incisions on both lateral chestwall and transferring such markings onto the pectus bar.

In all cases, the depressed sternum was first elevated by applying a sternal wire loop to the lateral border of the sternum at the deepest part (Figure 3a) and elevating it up by retracting on the sternal wire loop with a rib approximator attached to a Thompson retractor (Figures 3b and 3c). This is probably the single most important step in the procedure as it elevates the depressed sternum above the pericardium thus increasing the distance between the inner surface of the sternum and the pericardium, providing a straight path from one thoracic cavity to the other. Once this was accomplished, the pectus introducer was inserted into the right chestwall under direct vision from a thoracoscope (inserted via another port site above or below the introducer) or a pectoscope which is part of the introducer and tunnelled from the right thoracic cavity through the pericardial fat pad



Figs. 3: a) Insertion of sternal wire into the sternal plateau for sternal elevation, b) elevation of sternum by lifting the sternal wire loop by a rib approximator attached to a Thompson retractor arm, and c) actual sternal elevator during a live case of NUSS MIRPE.

just beneath the sternum and above the pericardium to the left thoracic cavity.

Once the pectus introducer was through both thoracic cavities, it was used to remodel the sternum by elevating the introducer while pressing down on the sternum onto the introducer. A 24Fr chest drain was then fixed to the tip of the introducer and withdrawn through the thoracic cavity to the right side. The pre-bent bar was then attached to the chest drain and pulled across to the left thoracic cavity. Twisting the pre-bent bar clock-wise on the right and anti-clockwise on the left together was performed to slot the bar into place and correct the deformity. Final steps involved introducing the stabilised plates (Park's hinge plate or Biomet rectangular plate) and anchoring them down with size 5 Ethibon sutures. The ends of the bar were fixed using either Park's claw fixator for Park's modified pectus bar or size 5 sternal wires or Ethibon sutures for Biomet pectus bar onto the adjacent rib. A 12Fr redivac drain was placed into each thoracic space and also the subcutaneous space where the metal plates were located to evacuate any collected blood.

Patients were extubated on the table with patient-controlled analgesia for pain relief. They were transferred back to the ward for monitoring and chest x-rays were performed immediately after the operation to assess the position of the bar. Antibiotics were continued until all drains were removed after 48 hours. Chest physiotherapy was started the next day and patients are advised to start ambulation on day-2 of surgery.

STATISTICAL ANALYSIS: All data are presented as mean and standard deviation and were analysed using Microsoft Excel (Microsoft, USA).

RESULTS

Since November 21, 2011, seven cases of MIRPE procedures have been performed successfully by our unit at RIPAS Hospital. These consisted of six primary MIRPE cases and one redo for bar displacement. Hence there were six patients, five males and one female with a mean age of 17 ± 2.3 years (range 14.6–20.7 years). Mean Haller index was 7.0 ± 4.2 (3.27 –15.33). The patient with the largest Haller index had a complete depression of the sternum, and her respiratory function showed severe restrictive pattern on pulmonary function test (FVC 1.58, FEV1 0.97). To achieve satisfactory repair, she required 2 bars to correct the depression. All patients were asymptomatic at referrals with mean FVC, FEV1 and LVEF of 3.6, 3.0 and 67% respectively.

The mean duration of procedure was 139.6 ± 57.1 min (85–230 min), with notable improvement in time for the last two cases down to an average of 86.5 min (Figure 4). Pectus bar used consisted of 3 Park's modified pectus bar and three Biomet pectus bar. For the first three patients who had used Park's modified pectus bar, stabilisation was achieved using two hinge plates and two claw fixators in each patient. For the last three patients, Biomet pectus bar was used and the bar was stabilised using a rectangular stabiliser. Mean duration of hospital stay was 5.3 ± 1.2 days (4-7 days).

There was one early post-operative complication from a wound haematoma, which was resolved with aspiration under ultrasound guidance. There were no pneumothoraxes in any of the patients. There was only one late complication due to bar displacement and recurrence of the PE deformity in the first patient that was performed in our unit, exactly four months after the primary procedure. This required a redo procedure and there has been no problem since. All patients achieved satisfactory repair with an average score of about eight but in two patients, costal flaring persists. There was no mortality.

DISCUSSION

Prior to the introduction of the minimally invasive NUSS or MIRPE procedure in 1998, the gold standard surgical treatment for PE was the Ravitch repair which was an open procedure involving a sub-perichondrial resection of all deformed costal cartilages, xiphoid resection and anterior wedge sternal osteotomy

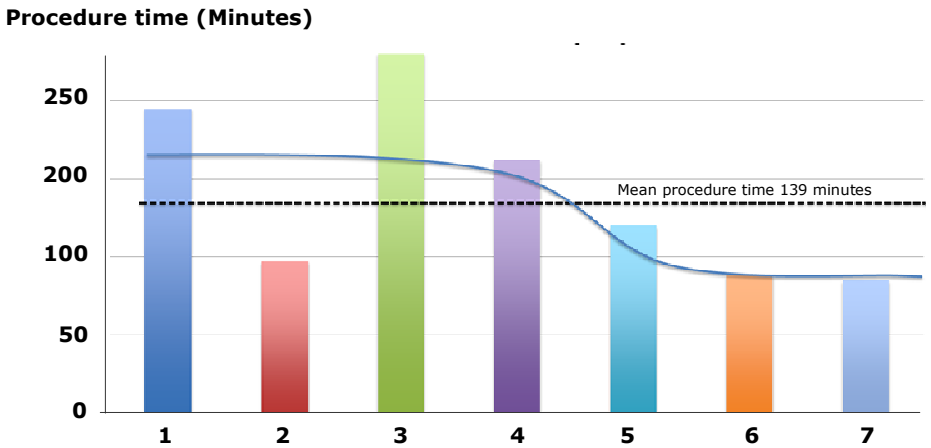


Fig. 4: MIRPE procedure times.

with wire fixation and a substernal bar or mesh support. [12] The approach to Ravitch repair is through a median longitudinal skin incision down to the sternum in male patients or a bilateral submammary incision in females to expose all the abnormal costal cartilage and depressed sternum. [3] This procedure is horrendous with significant blood loss and postoperative complications. With the introduction of NUSS or MIRPE, surgical repair of PE has been completely revolutionised and has come of age as befitting that of a 21st century procedure. Through two small lateral chestwall incisions, a pre-bent bar according to the contour of the deformity of PE, is introduced through both thoracic cavities under the deformed sternum to elevate it upwards for complete correction without any cartilage or sternal resection. [7] The bar is left in place for 2-3 years to allow for sternal remodelling to complete before it is removed. Using MIRPE, the scars are minimal and often unnoticeable with less blood loss, less pain, early mobilisation and perhaps shorter hospital stay.

Our unit started performing MIRPE in November 2011 and since then, we have performed 7 cases successfully without any major morbidities or mortality. Under expert supervision, the procedure can be taught and learned quickly with very sharp exponential learning curve (Figure 4). Results are reproducible and satisfactory for both surgeons and patients.

One of the most important steps which cannot be dispensed off with MIRPE procedure is the sternal elevation which immediately corrects the sternal depression, lifting the under surface of the sternum above the pericardium and the heart, creating the normal space that usually exists between the under surface of the sternum and pericardium. This potential space allows for the safe delivery of the pectus introducer across from the right to the left thoracic cavity (Figure 2b). With thoracoscopic vision, this can be safely performed avoiding any pericardial or cardiac injuries, which have been previously reported. [13] This method of sternal elevation has been previosuly reported by various authors to avoid cardiac or pericardial injuries during introduction of the pectus introducer. [13-15]

Pre-bending of the bar using the MM-MT Terrain contour-matching technique ensures that the defect of PE can be corrected completely, particularly when dealing with asymmetrical morphological types of PE. [12] Six bar shapes have been described to address the different morphological types of PE, such as the classic symmetrical bar, the bridge, the asymmetric, the seagull, the hump and the compound bar. [16] Furthermore, knowledge of crest compression enables one to fully correct any crest asymmetry present in PE by pre-bending the bar to compress or elevate the crest.

Due to the minimally invasive nature of the MIRPE procedure, blood loss is considerably less than conventional open repair. [17] All seven cases of MIRPE performed at our unit were safely and successfully performed without any need for blood transfusion and blood loss recorded was negligible. Operative time has also been reported to be shorter with MIRPE than conventional open repair. [17, 18] In terms of functional improvements, MIRPE procedure has been repeatedly shown to significantly improve cardio-respiratory functions as

well as psychosocial and and physical functions in the long term. [11, 19, 20]

In conclusion, our unit's early experience in performing MIRPE procedure for PE has been satisfactory both for surgeons and patients alike. Certainly, certain tricks and maneuvers during the procedure such as sternal lifting, makes the procedure fairly safe and the MM-MT Terrain contour-matching techniques with added crest compression during bar bending ensures that MIRPE is universally applicable to all morphological types of PE.

Acknowledgements:

I would like to acknowledge the tremendous help in general as well as technical advice given by both Professor Hyung Joo Park and Professor Sookwhan Sung, from the Seoul St Mary's Hospital, Catholic University of Korea, during the PE workshop in November 2011 and for their efforts in helping us set up our MIRPE unit in Brunei Darussalam.

REFERENCES

1: Kelly RE Jr, Shamberger RC, Mellins RB, et al. Prospective multicenter study of surgical correction of pectus excavatum: design, perioperative complications, pain, and baseline pulmonary function facilitated by internet-based data collection. J Am Coll Surg. 2007; 205:205–16.

2: Žganjer M, Žganjer V. Surgical correction of the funnel chest deformity in children. Int Orthop. 2011; 35:1043–8.

3: Brochhausen C, Turial S, Müller FKP, et al. Pectus excavatum: history, hypotheses and treatment options. Interact Cardiovasc Thorac Surg. 2012; 14:801–6.

4: David VL, Izvernariu DA, Popoiu CM, Puiu M, Boia ES. Morphologic, morphometrical and histochemical proprieties of the costal cartilage in children with pectus excavatum. Rom J Morphol Embryol. 2011; 52:625–9.

5: Fonkalsrud EW, Dunn JC, Atkinson JB. Repair of pectus excavatum deformities: 30 years of experi ence with 375 patients. Ann Surg 2000; 231:443–8.

6: Colombani PM. Preoperative assessment of chest wall deformities. Semin Thorac Cardiovasc Surg 2009; 21:58–63.

7: Lawson ML, Mellins RB, Paulson JF, et al. Increasing severity of pectus excavatum is associated with reduced pulmonary function. J Pediatr. 2011; 159:256–61.e2.

8: Lesbo M, Tang M, Nielsen HH, et al. Compromised cardiac function in exercising teenagers with pectus excavatum. Interact Cardiovasc Thorac Surg. 2011; 13:377–80.

9: Swanson JW, Avansino JR, Phillips GS, et al. Correlating Haller Index and cardiopulmonary disease in pectus excavatum. Am J Surg 2012; 203:660–4.

10: Nuss D, Kelly RE Jr, Croitoru DP, Katz ME. A 10 -year review of a minimally invasive technique for the correction of pectus excavatum. J Pediatr Surg 1998; 33:545–52.

11: Kelly RE Jr, Cash TF, Shamberger RC, et al. Surgical repair of pectus excavatum markedly improves body image and perceived ability for physical activity: multicenter study. Pediatrics. 2008; 122:1218–22.

12: Park HJ. Technical innovations in the minimally invasive approach for treating pectus excavatum: a paradigm shift through six years' experience with 630 patients. Innovations (Phila). 2007; 2:25–8.

13: Belcher E, Arora S, Samancilar O, Goldstraw P. Reducing cardiac injury during minimally invasive repair of pectus excavatum. Eur J Cardiothorac Surg 2008; 33:931–3.

14: Onishi K, Maruyama Y. Correction of pectus excavatum using a sternal elevator: preliminary report. Br J Plast Surg. 2001; 54:117–24.

15: Takagi S, Oyama T, Tomokazu N, Kinoshita K, Makino T, Ohjimi H. A new sternum elevator reduces severe complications during minimally invasive repair of the pectus excavatum. Pediatr Surg Int. 2012; 28:623–6.

16: Park HJ, Lee SY, Lee CS, Youm W, Lee KR. The Nuss procedure for pectus excavatum: evolution of techniques and early results on 322 patients. Ann

Thorac Surg. 2004; 77:289–95.

17: Boehm RA, Muensterer OJ, Till H. Comparing minimally invasive funnel chest repair versus the conventional technique: an outcome analysis in children. Plast Reconstr Surg 2004; 114:668–73; discussion 674–5.

18: Fonkalsrud EW, Beanes S, Hebra A, Adamson W, Tagge E. Comparison of minimally invasive and modified Ravitch pectus excavatum repair. J Pediatr Surg. 2002; 37:413–7.

19: Malek MH, Berger DE, Housh TJ, Marelich WD, Coburn JW, Beck TW. Cardiovascular function following surgical repair of pectus excavatum: a metaanalysis. Chest. 2006; 130:506–16.

20: Chen Z, Amos EB, Luo H, et al. Comparative pulmonary functional recovery after Nuss and Ravitch procedures for pectus excavatum repair: a meta-analysis. J Cardiothorac Surg. 2012; 7:101.